Weed Technology 2009 23:384–390

In-Crop and Autumn-Applied Glyphosate Reduced Purple Nutsedge (*Cyperus rotundus*) Density in No-Till Glyphosate-Resistant Corn and Soybean

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A 3-yr field study was conducted from 2005 to 2007 at Stoneville, MS, to determine efficacy of in-crop and autumn-applied glyphosate on purple nutsedge density and yield of no-till glyphosate-resistant (GR) corn and GR soybean. Separate experiments were conducted in GR corn and GR soybean in areas maintained under a no-tillage system after the autumn of 2004. Each experiment was conducted in a split-plot arrangement of treatments in a randomized complete-block design with and without autumn application of glyphosate at 1.68 kg ae/ha as main plots and in-crop herbicide application (glyphosate- and nonglyphosate-based programs) as subplots with three replications. In GR corn, glyphosate applied in the autumn reduced purple nutsedge density by 40 to 67% compared with no glyphosate during 3 yr. In GR corn, glyphosate applied in-crop reduced purple nutsedge shoot density by 48% in 2005, 92% in 2006, and 100% in 2007 compared with no herbicide. However, GR corn yields were unaffected by either in-crop or autumn-applied glyphosate. In GR soybean, glyphosate applied in the autumn reduced purple nutsedge shoot density by 64 to 83% compared with no glyphosate during 3 yr. Glyphosate applied in-crop in GR soybean reduced purple nutsedge density by 81% in 2005 and by 100% in 2006 and 2007 compared with no herbicide. GR soybean yields were similar in 2005, but yields were 34 and 18% higher in 2006 and 2007, respectively, with autumn-applied glyphosate compared with no glyphosate. GR soybean yields were higher with glyphosate applied in-crop compared with no herbicide in 2 of 3 yr. These results indicate that purple nutsedge density could be reduced with glyphosate applied in-crop in no-till GR corn and GR soybean. In addition, autumn-applied glyphosate was effective in reducing purple nutsedge populations following harvest of crops and could be an effective purple nutsedge management strategy regardless of GR trait.

Nomenclature: Glyphosate; chlorimuron; halosulfuron; *S*-metolachlor; purple nutsedge, *Cyperus rotundus* L. CYPRO; corn, *Zea mays* L.; soybean, *Glycine max* (L.) Merr.

Key words: Conservation tillage, transgenic crop, weed density, weed management.

Purple nutsedge is one of about 600 species of *Cyperus* worldwide (Tucker et al. 2002) and one of the 149 species in the genus cited as weeds (Bryson and Carter 2008). According to Holm et al. (1977), purple nutsedge is considered the world's worst weed because of its ability to survive, spread, and compete, especially in disturbed and agricultural areas. It is a weed on every continent except Antarctica (Holm et al. 1977). Purple nutsedge has been reported in 52 crops and 92 countries (Holm et al. 1977). It was speculated to have been introduced into the United States before 1800 because purple nutsedge, then known as *C. hydra* Michx., was described as a "scourge" of plantations in Georgia and South Carolina by Elliott (1821).

Purple nutsedge rarely sets viable seeds, and its spread is dependent on numerous rhizomes and tubers (Holm et al. 1977; Thullen and Keeley 1979). Tubers may remain dormant for long periods during cold, drought, flooding, heat, or inadequate aeration (Bendixen and Nandihalli 1987; Miles et al. 1996; Wills 1987), which makes purple nutsedge control very difficult. The earliest control strategy recommended was daily tilling of the soil (Elliott 1821). Since the advent of herbicides, few have been effective in controlling purple nutsedge selectively, and no herbicides eliminate dormant tubers, thus population reductions require multiple applications for multiple years (Akin and Shaw 2001; Bryson et al. 2003; Keeley and Thullen 1971; Pereira et al. 1987; Rao and Reddy 1999; Webster et al. 2008).

Purple nutsedge was listed among the 10 most common and troublesome weeds in soybean (Webster 2005) and corn (Webster 2008) in several states in the southern United States. In 2000, purple nutsedge was among the 20 most common weeds infesting soybean fields in Mississippi with an average density of 4 shoots/m^2 (Rankins et al. 2005). Although purple nutsedge is a relatively short plant, when compared with many weed species, it can be a strong competitor because of an extensive network of underground rhizomes and tubers (Patterson 1982), and it has been reported to produce allelochemicals (Bryson and Carter 2008; Keeley 1987). Yield losses from purple nutsedge interference in both agronomic and horticultural crops have been widely documented (Keeley 1987).

Glyphosate has considerable activity on purple nutsedge and has effectively reduced populations in various cropping systems (Akin and Shaw 2001; Bariuan et al. 1999; Bryson et al. 2003, Edenfield et al. 2005; Webster et al. 2008; Zandstra and Nishimoto 1977). The extent of purple nutsedge control is dependent on amount of foliage; glyphosate rate, time, and number of applications; and crop production practices, as well as soil tuber bank. Although, glyphosate in-crop POST applications in glyphosate-resistant (GR) crops provide purple nutsedge control, control may be temporary in severely infested fields (Akin and Shaw 2001; Edenfield et al. 2005; Webster et al. 2008). Purple nutsedge can reestablish by regrowth of plants and resprouting of tubers that were not killed by glyphosate because of limited translocation (Bariuan

DOI: 10.1614/WT-09-016.1

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et al. 1999). New plants can also arise subsequently from tubers because of remaining dormant and tubers escaping glyphosate treatment.

In the southern United States, corn and soybean are harvested beginning in August. The time between harvest and frost provides a favorable environment for purple nutsedge to reestablish and replenish tubers, sustaining future infestations. Purple nutsedge can produce new tubers within 16 d of shoot emergence, and tuber production continues at a rate of one every 4 d (Hammerton 1974). Postharvest, follow-up glyphosate application can extend purple nutsedge control and reduce tuber replenishment. Treating purple nutsedge with glyphosate at higher than in-crop use rates in October can enhance herbicide translocation to underground parts and reduce future infestations. Whether this strategy can help manage purple nutsedge was the focus of this investigation. The specific objectives of this study were to determine efficacy of glyphosate in-crop POST and autumn applications on purple nutsedge populations and GR corn and GR soybean yields. Purple nutsedge populations were monitored, assigning the treatments to the same plots over a 3-yr period, to assess cumulative effects of glyphosate in GR corn and GR soybean under a no-tillage system.

Materials and Methods

General Conditions. Two field studies were conducted from 2005 to 2008 at the U.S. Department of Agriculture–Agricultural Research Service, Southern Weed Science Research Unit farm, Stoneville, MS (33°26′N, 90°55′W). The soil was a Dundee silt loam (fine-silty, mixed, active, thermic Typic Endoaqualfs) with pH 6.7, 1.1% organic matter, a cation exchange capacity of 15 cmol/kg, and soil textural fractions of 26% sand, 55% silt, and 19% clay. The experimental area was predominantly and uniformly infested with purple nutsedge. In 2003, the experimental area was disked and smooth-tooth cultivated in the spring, treated with metolachlor (1.68 kg ai/ha), bentazon (0.84 kg ai/ha), and clethodim (0.14 kg ai/ha) in the summer to select for purple nutsedge. In 2004, the experimental area was treated with 2,4-D (1.12 kg ae/ha), acifluorfen (0.28 kg ai/ha), bentazon (0.56 kg ai/ha), fluometuron (1.12 kg ai/ha), metolachlor (1.68 kg ai/ha), and sethoxydim (0.42 kg ai/ha) as needed to selectively establish purple nutsedge. Bentazon and metolachlor were used to select purple nutsedge vs. yellow nutsedge (*Cyperus esculentus* L.). In the autumn of 2004, land was deep-tilled, disk-harrowed, spring-tooth cultivated, and bedded for corn and left flat for soybean. The land received no tillage operations after the autumn of 2004. The commercial formulation of potassium salt of glyphosate[1] was used with no additional adjuvant. All herbicide treatments except late POST (LPOST) in corn were applied broadcast with a tractor-mounted sprayer with 8004 standard, flat spray nozzles,[2] delivering 187 L/ha water. The LPOST treatments in corn were applied broadcast using a hooded sprayer equipped with off-centered nozzles (OC-01 flat spray tips) for POST-direct spraying and sprayer hoods with three nozzles (95002 even, flat spray tips) for spraying between the rows.

Corn Study. This study was conducted to determine the effectiveness of glyphosate applied in-crop POST and in the autumn on purple nutsedge populations in no-till GR corn. The experiment was conducted in split-plot arrangement of treatments in a randomized complete-block design, with autumn application as main plots and in-crop application as subplots, with three replications. Each subplot consisted of four corn rows spaced 102 cm apart and 13.7 m long. Treatments were assigned to the same plots in all 3 yr to assess the effect of consecutive in-crop and autumn applications on purple nutsedge populations. Main plot treatments were autumn application of glyphosate at 1.68 kg ae/ha or no glyphosate. Subplot treatments were glyphosate applied early POST (EPOST) at 0.84 kg/ha followed by (fb) glyphosate LPOST at 0.84 kg/ha with and without *S*-metolachlor applied PRE at 1.68 kg ai/ha, *S*-metolachlor PRE at 1.68 kg/ha fb halosulfuron EPOST at 0.07 kg ai/ha fb halosulfuron LPOST at 0.07 kg/ha, and a no-herbicide treatment (Table 1). GR corn hybrid 'DKC69-72RR2' was planted on March 31, 2005, March 15, 2006, and March 12, 2007. Corn was planted in 102-cm-wide rows using a planter[3] at 75,000 seeds/ha. PRE herbicide treatments were applied immediately after planting. EPOST and LPOST treatments were applied 4 to 5 and 6 to 7 wk after planting, respectively. At EPOST, purple nutsedge plants were 2 to 20 cm tall and had 2 to 10 leaves, depending on time of emergence. Fertilizer application and insect control programs were standard for corn, and the crop was irrigated on an as-needed basis each year. Corn from all four rows was harvested on August 18, 2005, August 16, 2006, and August 13, 2007, using a combine, and grain yield was adjusted to 15% moisture. After harvest, glyphosate was applied to reestablished purple nutsedge (2 to 20 cm tall, 2 to 10 leaves) during the second week of October in 2005, 2006, and 2007.

Soybean Study. This study was also conducted under a no-tillage system, adjacent to the corn study. The experiment was conducted in split-plot arrangement of treatments in a randomized complete-block design with autumn application as main plots and in-crop application as subplots, with three replications. Each subplot consisted of eight soybean rows 13.7 m long, spaced 51 cm apart. Treatments were assigned to the same plots in all 3 yr to assess the effect of consecutive in-crop and autumn applications on purple nutsedge populations. Main plot treatments were autumn application of glyphosate at 1.68 kg ae/ha and no glyphosate control. Subplot treatments were glyphosate EPOST at 0.84 kg/ha fb glyphosate LPOST at 0.84 kg/ha with and without *S*-metolachlor PRE at 1.68 kg/ha, *S*-metolachlor PRE at 1.68 kg/ha fb chlorimuron EPOST at 0.013 kg ai/ha fb chlorimuron LPOST at 0.013 kg/ha, and a no herbicide control. GR soybean cultivars and planting dates were 'AG4603RR' on April 19, 2005; 'AG4503RR' on April 13, 2006; and 'AG4604RR' on April 19, 2007. Cultivars were selected based on regional use patterns by producers and seed availability. Soybean was planted in 51-cm-wide rows using a Monosem NG plus precision planter[4] at 285,000 seeds/ha. The PRE herbicide treatments were applied immediately after planting. The EPOST and LPOST treatments were applied 4 and 6 wk after planting, respectively. The soybean study was

Table 1. Purple nutsedge density as affected by in-crop and autumn-applied glyphosate in no-till glyphosate-resistant corn at Stoneville, MS, 2005 to 2008.[a]

Treatment				Purple nutsedge density						
	In-crop application			2005		2006		2007		2008
Autumn application[b]	Herbicide	Rate	Timing[c]	April	May	April	May	April	June	May
		kg/ha		shoots/m²						
No glyphosate	No herbicide	—	—	178	151	316	316	305	373	400
	Glyphosate	0.84	EPOST	178	111	115	39	34	2	27
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	165	52	63	11	11	0	32
	Glyphosate	0.84	EPOST							
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	172	18	133	2	12	0	7
	Halosulfuron	0.07	EPOST							
	Halosulfuron	0.07	LPOST							
	Mean			173	83	157	92	91	94	117
Glyphosate	No herbicide		—	196	163	150	248	151	203	214
	Glyphosate	0.84	EPOST	194	50	25	5	16	0	36
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	188	30	22	4	2	0	26
	Glyphosate	0.84	EPOST							
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	165	47	13	0	2	0	4
	Halosulfuron	0.07	EPOST							
	Halosulfuron	0.07	LPOST							
	Mean			185	73	52	64	43	51	70
Mean	No herbicide		—	186	157	233	282	228	288	307
	Glyphosate	0.84	EPOST	185	81	70	22	25	< 1	31
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	177	41	42	7	6	0	29
	Glyphosate	0.84	EPOST							
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	167	32	73	< 1	7	0	5
	Halosulfuron	0.07	EPOST							
	Halosulfuron	0.07	LPOST							
LSD (0.05)[d]	Autumn-applied			NS	NS	91	NS	43	43	23
	In-crop			NS	56	91	81	60	61	32
	Interaction			NS	NS	128	NS	86	87	45

[a] The counts of purple nutsedge in April were recorded on the day of EPOST and in May/June were recorded at 2 wk after LPOST in 2005, 2006, and 2007. In 2008, no glyphosate was applied, and data reflect terminal density of purple nutsedge at the end of the 3-yr study.

[b] Glyphosate at 1.68 kg ae/ha was applied during the second week of October in 2005, 2006, and 2007.

[c] Abbreviations: EPOST, early postemergence; LPOST, late postemergence; NS, not significant; PRE, preemergence.

[d] Definitions: Autumn-applied, LSD for autumn-applied mean separation; in-crop, LSD for in-crop mean separation; interaction, LSD for autumn-applied by in-crop herbicide interaction.

conducted in a nonirrigated environment. Soybean from all eight rows was harvested on September 6, 2005, August 23, 2006, and August 21, 2007 using a combine, and grain yield was adjusted to 13% moisture. After harvest, glyphosate was applied in the autumn as described in the corn study.

In both corn and soybean studies, purple nutsedge shoots were counted in two randomly selected 0.09-m² areas between the center two rows of each plot. Purple nutsedge shoot counts were taken on the day of EPOST and 2 wk after LPOST applications in 2005, 2006, and 2007. Purple nutsedge shoots were counted at the end of a 3-yr study on May 9, 2008, to assess the overall, effect of in-crop and autumn-applied glyphosate on purple nutsedge population. Data were subjected to analysis of variance using PROC MIXED[5], and treatment means were separated at the 5% level of significance using Fisher's Protected LSD test.

Results and Discussion

Corn Study. There were no differences in purple nutsedge shoot density among autumn and in-crop glyphosate treatments in April 2005, at the beginning of a 3-yr study (Table 1). However, differences in purple nutsedge shoot densities became apparent in subsequent years. Glyphosate applied in the autumn of 2005, 2006, and 2007 decreased purple nutsedge shoot densities (averaged across in-crop herbicides) in the following spring by 67% (April 2006), 53% (April 2007), and 40% (May 2008), respectively, compared with no glyphosate. Interactions between autumn-applied and in-crop herbicide treatments also suggest that autumn-applied glyphosate was detrimental to purple nutsedge. In in-crop no-herbicide check plots, autumn-applied glyphosate reduced purple nutsedge shoot density by 53, 51, and 47% in April

2006, April 2007, and May 2008, respectively, compared with no glyphosate (Table 1).

All in-crop herbicide treatments controlled purple nutsedge effectively compared with no herbicide in all 3 yr. Glyphosate applied EPOST fb LPOST reduced purple nutsedge shoot density (averaged across autumn-applied glyphosate) by 48% in May 2005, 92% in May 2006, and 100% in June 2007 compared with no herbicide (Table 1). The gradual increase in control from 2005 to 2007 could be attributed to cumulative effect of glyphosate on purple nutsedge. A similar trend was observed with glyphosate or halosulfuron EPOST fb LPOST following *S*-metolachlor PRE. *S*-metolachlor PRE fb halosulfuron EPOST fb LPOST was included as a standard herbicide program commonly used in non-GR corn. *S*-metolachlor has little or no activity (Akin and Shaw 2001; Anonymous 2009), and halosulfuron has considerable activity (Anonymous 2008; Norsworthy et al. 2007; Rao and Reddy 1999) on purple nutsedge. Glyphosate EPOST fb LPOST was as effective as *S*-metolachlor PRE fb halosulfuron EPOST fb LPOST in complete control of purple nutsedge populations in this 3-yr study. Other researchers have shown that glyphosate and halosulfuron applied alone or in combination completely controlled 3- and 6-wk-old purple nutsedge under greenhouse conditions (Rao and Reddy 1999). Taken together, these data suggest that glyphosate and halosulfuron applied sequentially or in combination could be an effective strategy to manage severe infestations of purple nutsedge in GR corn.

There were no differences in corn grain yields between autumn-applied glyphosate and no glyphosate or among four in-crop herbicide treatments in all 3 yr (data not shown). Corn yields ranged from 9,970 to 10,920 kg/ha in 2005; 8,300 to 9,320 kg/ha in 2006; and 8,600 to 9,540 kg/ha in 2007 among autumn and in-crop applied herbicide treatments. Corn yields were unaffected despite severe infestations of purple nutsedge. For example, in June 2007, the average purple nutsedge density was higher (288 vs. < 1 shoot/m^2) in no-herbicide plots compared with the three in-crop herbicide treatments (Table 1). Apparently, corn is highly competitive with purple nutsedge. Purple nutsedge height being relatively short was suppressed by tall, fast-growing corn, thus reducing its competitive potential (Edenfield et al. 2005).

Soybean Study. Similar to corn study, there were no differences in purple nutsedge shoot density among autumn and in-crop glyphosate treatments in May 2005, at the beginning of a 3-yr study (Table 2). However, differences in purple nutsedge shoot densities became apparent in subsequent years. Glyphosate applied in the autumn of 2005, 2006, and 2007 consistently decreased purple nutsedge shoot densities (averaged across in-crop herbicides) in the following spring by 83% (May 2006), 64% (May 2007), and 66% (May 2008), respectively, compared with no autumn glyphosate. Interactions between autumn-applied and in-crop herbicide treatments also suggest that autumn-applied glyphosate was detrimental to purple nutsedge. In in-crop no-herbicide check plots, autumn-applied glyphosate reduced purple nutsedge shoot density by 79, 64, and 71% in May 2006, May 2007, and May 2008, respectively, compared with no glyphosate (Table 2).

All in-crop herbicide treatments controlled purple nutsedge effectively compared with no herbicide in all 3 yr. Glyphosate applied EPOST fb LPOST reduced purple nutsedge shoot density (averaged across autumn-applied glyphosate) by 81% in June 2005 and 100% in June 2006 and 2007 compared with no herbicide (Table 2). A similar trend was observed with glyphosate or chlorimuron EPOST fb LPOST following *S*-metolachlor PRE. *S*-metolachlor PRE fb chlorimuron EPOST fb LPOST was included as a standard herbicide program commonly used in non-GR soybean. *S*-metolachlor has little or no activity (Akin and Shaw 2001; Anonymous 2009), and chlorimuron has considerable activity (Rao and Reddy 1999; Reddy and Bendixen 1988) on purple nutsedge. Glyphosate EPOST fb LPOST was equally effective compared with *S*-metolachlor PRE fb chlorimuron EPOST fb LPOST in reducing purple nutsedge populations in this 3-yr study.

Soybean yields were unaffected by autumn-applied glyphosate in 2005, but yields in 2006 and 2007 were increased by 18 to 34% with autumn-applied glyphosate compared with no glyphosate (Table 3). All in-crop herbicide treatments increased soybean yield compared with no herbicide in 2005 and 2007. In 2006, soybean yields were unaffected despite higher populations of purple nutsedge (406 shoots/m^2) in the untreated plot compared with all three in-crop herbicide treatments (1 to 58 shoots/m^2) (Table 2). Overall, soybean yields were lower in 2006 compared with 2005 and 2007. Soybean was grown nonirrigated in all 3 yr, and in 2006, visible soil moisture-related stress occurred during June–July because of 27 to 69% less rainfall than in 2005 and 2007 (Table 4).

There was a window of 40 to 60 d between corn or soybean harvest in August and autumn application of glyphosate in October for all 3 yr. Absence of interference from crops following harvest coupled with warm and moist growing conditions (Table 4) provided an environment conducive for purple nutsedge to reestablish and replenish tubers. Purple nutsedge densities (averaged over autumn glyphosate plots) in October of 2005, 2006, and 2007, ranged from 21 to 75 shoots/m^2 in corn and 27 to 173 shoots/m^2 in soybean (data not shown). Actively growing purple nutsedge plants with abundant foliage may have effectively intercepted glyphosate spray and translocated herbicide to rhizomes and tubers. It has been documented that glyphosate is readily absorbed through foliage and translocates to tubers in purple nutsedge (Bariuan et al. 1999; Zandstra and Nishimoto 1977). Glyphosate is known to reduce regrowth of plants and resprouting of tubers (Bariuan et al. 1999; Rao and Reddy 1999) and to reduce tuber production (Webster et al. 2008) in purple nutsedge. In this study, glyphosate at a rate of 1.68 kg/ha, applied in the autumn, greatly reduced purple nutsedge densities in both corn and soybean. In other research, glyphosate at 2.52 kg/ha, applied preplant, reduced density of trumpetcreeper [*Campsis radicans* (L.) Seem. ex Bureau], a perennial vine, by 25 to 44% compared with no glyphosate in GR soybean (Reddy 2005). Glyphosate applied preplant may not be as effective on purple nutsedge as glyphosate applied in the autumn. Because of cool and wet growing conditions in early spring (Table 4), purple nutsedge usually does not have enough foliage to

Table 2. Purple nutsedge density as affected by in-crop and autumn-applied glyphosate in no-till glyphosate-resistant soybean at Stoneville, MS, 2005 to 2008.[a]

Treatment				Purple nutsedge density						
	In-crop application			2005		2006		2007		2008
Autumn application[b]	Herbicide	Rate	Timing[c]	May	June	May	June	May	June	May
		kg/ha		shoots/m^2						
No glyphosate	No herbicide	—	—	165	343	891	556	705	603	876
	Glyphosate	0.84	EPOST	109	47	65	4	5	0	2
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	108	41	99	2	18	0	7
	Glyphosate	0.84	EPOST							
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	124	133	233	113	133	22	92
	Chlorimuron	0.013	EPOST							
	Chlorimuron	0.013	LPOST							
	Mean			127	141	322	169	215	156	244
Glyphosate	No herbicide		—	124	321	187	257	257	264	258
	Glyphosate	0.84	EPOST	142	79	7	0	4	0	2
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	169	72	4	0	11	0	2
	Glyphosate	0.84	EPOST							
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	147	144	23	4	40	0	72
	Chlorimuron	0.013	EPOST							
	Chlorimuron	0.013	LPOST							
	Mean			145	154	55	65	78	66	83
Mean	No herbicide		—	144	332	539	406	481	433	567
	Glyphosate	0.84	EPOST	126	63	36	2	5	0	2
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	138	57	51	< 1	14	0	4
	Glyphosate	0.84	EPOST							
	Glyphosate	0.84	LPOST							
	S-metolachlor	1.68	PRE	136	138	128	58	86	11	82
	Chlorimuron	0.013	EPOST							
	Chlorimuron	0.013	LPOST							
LSD (0.05)[d]	Autumn-applied			NS	NS	103	91	NS	74	48
	In-crop			NS	53	86	129	84	105	67
	Interaction			NS	NS	130	182	132	148	95

[a] The counts of purple nutsedge in May were recorded on the day of EPOST and in June were recorded at 2 wk after LPOST in 2005, 2006, and 2007. In 2008, no glyphosate was applied, and data reflect terminal density of purple nutsedge at the end of the 3-yr study.

[b] Glyphosate at 1.68 kg ae/ha was applied during the second week of October in 2005, 2006, and 2007.

[c] Abbreviations: EPOST, early postemergence; LPOST, late postemergence; NS, not significant; PRE, preemergence.

[d] Definitions: Autumn-applied, LSD for autumn-applied mean separation; in-crop, LSD for in-crop mean separation; interaction, LSD for autumn-applied by in-crop herbicide interaction.

Table 3. Effect of in-crop POST and autumn application of glyphosate on no-till glyphosate-resistant soybean yield at Stoneville, MS, 2005 to 2007.[a,b]

Treatment			Soybean yield		
Main effect	Rate	Timing	2005	2006	2007
	kg/ha		kg/ha		
Autumn application					
No glyphosate	—	—	4,000 a	1,970 b	3,310 b
Glyphosate	1.68	October[c]	4,250 a	2,640 a	3,900 a
In-crop postemergence					
No herbicide	—	—	3,490 b	2,110 a	3,130 b
Glyphosate	0.84	EPOST	4,480 a	2,580 a	3,830 a
Glyphosate	0.84	LPOST			
S-metolachlor	1.68	PRE	4,300 a	2,320 a	3,930 a
Glyphosate	0.84	EPOST			
Glyphosate	0.84	LPOST			
S-metolachlor	1.68	PRE	4,220 a	2,210 a	3,530 ab
Chlorimuron	0.013	EPOST			
Chlorimuron	0.013	LPOST			

[a] Abbreviations: EPOST, early postemergence; LPOST, late postemergence; PRE, preemergence.

[b] Means within a column, for each main effect followed by same letter, are not significantly different at the 5% level as determined by Fisher's Protected LSD test.

[c] Glyphosate at 1.68 kg ae/ha was applied during the second week of October in 2005, 2006, and 2007.

Table 4. Average daily maximum and minimum air temperatures and monthly rainfall for 2005, 2006, and 2007 at Stoneville, MS.

Month	2005 Daily air temperature Maximum	2005 Daily air temperature Minimum	2005 Monthly rainfall	2006 Daily air temperature Maximum	2006 Daily air temperature Minimum	2006 Monthly rainfall	2007 Daily air temperature Maximum	2007 Daily air temperature Minimum	2007 Monthly rainfall
	C		cm	C		cm	C		cm
January	13.8	4.1	10.5	16.1	3.9	19.3	11.7	2.2	15.0
February	14.4	5.6	8.3	11.1	1.1	14.7	12.8	0.6	4.5
March	17.8	6.1	7.6	19.4	6.7	13.8	24.4	10.0	1.7
April	24.4	12.2	11.5	26.7	15.0	18.8	22.8	10.6	8.6
May	28.3	16.1	5.4	28.9	17.2	7.3	30.0	17.8	3.2
June	31.7	20.6	1.9	32.8	20.6	4.6	32.8	21.1	9.9
July	33.3	22.8	10.6	33.9	22.2	4.5	31.7	21.7	19.7
August	35.6	22.8	5.8	35.6	22.8	4.0	36.7	23.3	8.7
September	33.3	20.0	17.9	30.6	16.1	6.9	31.1	19.4	11.8
October	26.1	11.1	0	25.0	11.1	21.9	26.1	12.8	10.7
November	21.7	7.2	5.3	18.3	5.6	6.6	19.4	6.7	5.0
December	11.7	0	9.6	13.9	2.8	18.9	16.1	4.4	9.4

intercept sufficient spray droplets for the translocation of lethal amounts of glyphosate to underground parts.

After harvest of corn and soybean, many annual and perennial weeds emerge, establish, and replenish soil propagule/seed banks. These so called weeds after crop are becoming major weed problems in the lower Mississippi River valley alluvial flood plain, especially under no-tillage and reduced-tillage crop production systems. Most growers commonly perform various tillage operations when the seedbeds are prepared in the autumn. Yet, tillage alone cannot completely prevent purple nutsedge reestablishment. Even after seedbed preparation, if conditions are favorable, purple nutsedge can reestablish and produce numerous tubers in a short time. A purple nutsedge tuber can sprout multiple times; tuber production can begin in 16 d, and plants can produce nine tubers in 51 d (Hammerton 1974). In a no-tillage crop production system, management of perennial weeds, such as purple nutsedge, defaults to chemical methods because tillage is not an option. This study has shown that glyphosate application in the autumn can be an effective strategy for long-term management of purple nutsedge.

In summary, glyphosate applied in the autumn alone reduced purple nutsedge densities considerably in both corn and soybean grown under a no-tillage system. Similarly, glyphosate in-crop applications also effectively reduced purple nutsedge densities in both crops. At the end of this 3-yr study, both autumn-applied and in-crop applied glyphosate provided effective control of purple nutsedge. Effective long-term management of purple nutsedge requires repeated applications of glyphosate at higher rates than in-crop use rates. Based on relative densities of purple nutsedge in untreated plots at the end of 3-yr study, it appears that corn is more competitive with purple nutsedge than soybean. Relatively short purple nutsedge was shaded by tall, fast-growing corn, thus reducing its competitiveness. These results demonstrated that autumn-applied glyphosate was effective in preventing reestablishment of purple nutsedge following harvest of crops and autumn application of glyphosate could be an effective management strategy regardless of the crop's glyphosate-resistant trait.

Sources of Materials

[1] Potassium salt of glyphosate, Roundup WeatherMAX, Monsanto Agricultural Company, 800 North Lindbergh Boulevard, St. Louis, MO 63167.

[2] TeeJet standard flat spray nozzles, Spraying Systems Co., North Avenue and Schmale Road, Wheaton, IL 60189.

[3] MaxEmerge 2 planter, Deere and Co., 501 River Drive, Moline, IL 61265.

[4] Monosem NG Plus precision planter, Monosem ATI, Inc., 17135 West 116th Street, Lenexa, KS 66219.

[5] SAS proprietary software release 8.2 Windows version 5.1.2600, SAS Institute Inc., 92 Riverwood Drive, Fuquay Varina, NC 27526.

Acknowledgments

We thank Efren Ford, Terry Newton, and Albert Tidwell for technical assistance in field work. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

Literature Cited

Akin, D. S. and D. R. Shaw. 2001. Purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) control in glyphosate-tolerant soybean (*Glycine max*). Weed Technol. 15:564–570.

Anonymous. 2009. Dual II Magnum® herbicide product label. Syngenta Crop Protection Publication No. SCP 818A-L1M 0204. Greensboro, NC: Syngenta. 36 p. http://www.syngentacropprotection.com/pdf/labels/SCP818AL1M0204n.pdf. Accessed: January 28, 2009.

Anonymous. 2008. Permit® herbicide label. Gowan Company Publication No. 01-R0806EPA. Yuma, AZ: Gowan. 18 p. http://www.gowanco.com/ProductInfo~pid~75~Permit%20.aspx. Accessed: November 6, 2008.

Bariuan, J. V., K. N. Reddy, and G. D. Wills. 1999. Glyphosate injury, rainfastness, absorption, and translocation in purple nutsedge (*Cyperus rotundus*). Weed Technol. 13:112–119.

Bendixen, L. E. and U. B. Nandihalli. 1987. Worldwide distribution of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:61–65.

Bryson, C. T. and R. Carter. 2008. The significance of Cyperaceae as weeds. Pages 15–101 *in* R.F.C. Naczi and B. A. Ford, eds. Sedges: Uses, Diversity, and Systematics of the Cyperaceae. Monogr. Syst. Bot. Missouri Bot. Gard. 108.

Bryson, C. T., K. N. Reddy, and W. T. Molin. 2003. Purple nutsedge (*Cyperus rotundus*) population dynamics in narrow row transgenic cotton (*Gossypium hirsutum*) and soybean (*Glycine max*) rotation. Weed Technol. 17:805–810.

Edenfield, M. W., B. J. Brecke, D. L. Colvin, J. A. Dusky, and D. G. Shilling. 2005. Purple nutsedge (*Cyperus rotundus*) control with glyphosate in soybean and cotton. Weed Technol. 19:947–953.

Elliott, S. 1821. A Sketch of the Botany of South Carolina and Georgia. Volume 1. Charleston, SC: J.R. Schenck. 606 p.

Hammerton, J. L. 1974. Experiments with *Cyperus rotundus* L., I: growth and development and effects of 2,4-D and paraquat. Weed Res. 14:365–369.

Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. Honolulu: University Press of Hawaii. 609 p.

Keeley, P. E. 1987. Interference and interaction of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*) with crops. Weed Technol. 1:74–81.

Keeley, P. E. and R. J. Thullen. 1971. Control of nutsedge with organic arsenical herbicides. Weed Sci. 19:601–606.

Miles, J. E., R. K. Nishimoto, and O. Kawabata. 1996. Diurnally altering temperatures stimulate sprouting of purple nutsedge (*Cyperus rotundus*) tubers. Weed Sci. 44:122–125.

Norsworthy, J. H., J. Schroeder, S. H. Thomas, and L. W. Murray. 2007. Purple nutsedge (*Cyperus rotundus*) management in direct-seeded chile pepper using halosulfuron and cultivation. Weed Technol. 21:636–641.

Patterson, D. T. 1982. Shading responses of purple and yellow nutsedges (*Cyperus esculentus* and *C. rotundus*). Weed Sci. 30:25–30.

Pereira, W., G. Crabtree, and R. D. William. 1987. Herbicide action on purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:92–98.

Rankins, A., Jr., J. D. Byrd, Jr., D. B. Mask, J. W. Barnett, and P. D. Gerard. 2005. Survey of soybean weeds in Mississippi. Weed Technol. 19:492–498.

Rao, A. S. and K. N. Reddy. 1999. Purple nutsedge (*Cyperus rotundus*) and sicklepod (*Senna obtusifolia*) response to glyphosate mixtures with ALS-inhibiting herbicides. Weed Technol. 13:361–366.

Reddy, K. N. 2005. Deep tillage and glyphosate reduced redvine (*Brunnichia ovata*) and trumpetcreeper (*Campsis radicans*) populations in glyphosate-resistant soybean. Weed Technol. 19:713–718.

Reddy, K. N. and L. E. Bendixen. 1988. Toxicity, absorption, translocation, and metabolism of foliar-applied chlorimuron in yellow and purple nutsedge (*Cyperus esculentus* and *C. rotundus*). Weed Sci. 36:707–712.

Thullen, R. J. and P. E. Keeley. 1979. Seed production and germination in *Cyperus esculentus* and *C. rotundus*. Weed Sci. 27:502–505.

Tucker, G. C., B. G. Marcks, and J. R. Carter. 2002. *Cyperus*. Pages 141–191 *in* P. W. Ball, K. Gandhi, R. W. Kiger, D. Murray, J. L. Zarucchi, A. A. Reznicek and J. L. Strother, eds. Flora of North America. Volume 23. New York: Oxford University Press.

Webster, T. M. 2005. Weed survey—southern states. Proc. South. Weed Sci. Soc. 58:291–306.

Webster, T. M. 2008. Weed survey—southern states. Proc. South. Weed Sci. Soc. 61:224–243.

Webster, T. M., T. L. Grey, J. W. Davis, and A. S. Culpepper. 2008. Glyphosate hinders purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) tuber production. Weed Sci. 56:735–742.

Wills, G. D. 1987. Description of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:2–9.

Zandstra, B. H. and R. K. Nishimoto. 1977. Movement and activity of glyphosate in purple nutsedge. Weed Sci. 25:268–274.

Received February 5, 2009, and approved May 12, 2009.